PENNSTATE ARL

iMAST

Institute for Manufacturing and Sustainment Technologies

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY

2000 No.2

New Leaders Take the Helm

The Director of the Applied Research Laboratory is pleased to announce the selections of Dr. Thomas M. Donnellan as Associate Director for Materials and Manufacturing, and Mr. Robert B. Cook as director of the Institute for Manufacturing and Sustainment Technologies (iMAST).

MATERIALS AND MANUFACTURING

Dr. Thomas Donnellan joins ARL Penn State from the Federal Bureau of Investigation where he has been serving as Senior Scientist for materials science. Prior to the FBI, Dr. Donnellan served as manager of structural sciences for Northrop Grumman Corporation. Previous to Northrop Grumman, Dr. Donnellan was the composites group manager for the Naval Air Development Center (NADC) at Warminster, Pa.

"Tom Donnellan brings the required balance necessary to guide ARL's Materials and Manufacturing Division into the 21st Century," notes Dr. Ray Hettche, director of Penn State's Applied Research Laboratory. "Dr. Donnellan's technical research record, complimented by his industry and U.S. Navy management experience, are the right blend necessary to carry out the division's mission. I am delighted to have Tom on the staff."

A native of Pennsylvania, Dr. Donnellan received his bachelor of science degree in materials engineering from Drexel University. His post graduate education includes both a masters degree (polymerics) and a Ph.D. (material science) from the Massachusetts Institute of Technology.

iMAST

Mr. Robert Cook comes to iMAST from within Penn State's Applied Research Laboratory community where he has been serving as program manager for super-cavitation vehicles in the Fluids and Structural Mechanics Division.

No stranger to ARL's naval tradition, Mr. Cook formerly served as a career nuclear submarine officer prior to joining the Applied Research Laboratory at Penn State in 1998. In addition to serving as commander of the USS *Sea Devil* (SSN 664), Mr. Cook served as a program manager within the Naval Sea Systems Command (NAVSEA), and also within the Program Executive Office (PEO) for Submarines.

On the appointment of Robert Cook to director of iMAST, Dr. Ray Hettche notes, "Bob Cook brings sound programmatic experience with the U.S. Navy along with strong technical background and judgement. I believe he has the right tools necessary to work well with the Navy ManTech Program office. Bob will enhance the stated U.S. Navy ManTech objective of improving affordability for Navy and Marine Corps systems. I am delighted in adding Bob to a key role on our management staff."

A graduate of the U.S. Naval Academy with a degree in Ocean Engineering, Mr. Cook holds masters degrees in mechanical engineering and ocean engineering from the Massachusetts Institute of Technology.

FOCUS ON MATERIALS PROCESSING TECHNOLOGIES

Report Documentation Page					*Form Approved OMB No. 0704-0188*
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE **2000**		2. REPORT TYPE			3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **iMAST Quarterly, 2000 Number 2**					5a. CONTRACT NUMBER
					5b. GRANT NUMBER
					5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)					5d. PROJECT NUMBER
					5e. TASK NUMBER
					5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Penn State University,Applied Research Laboratory,Institute for Manufacturing and Sustainment Technologies,State College,PA,16804**					8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)					10. SPONSOR/MONITOR'S ACRONYM(S)
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

PENNSTATE

iMAST

Applied Research Laboratory
Institute for Manufacturing and Sustainment Technologies

DIRECTOR
Robert B. Cook
(814) 863-3880 rbc5@psu.edu

CHIEF SCIENTIST
Paul Kurtz, Ph.D.
(814) 865-2117 phk1@psu.edu

MATERIALS PROCESSING and DRIVETRAIN TECHNOLOGIES
Maurice F. Amateau, Ph.D.
(814) 863-4481 mfa1@psu.edu

LASER PROCESSING TECHNOLOGIES
Richard P. Martukanitz, Ph.D.
(814) 863-7282 rxm44@psu.edu

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES
James Sabo
(814) 865-3058 jxs45@psu.edu

NAVY/MARINE CORPS REPAIR TECHNOLOGIES
Sean Kreiger
(814) 863-0896 slk22@psu.edu

iMAST ADMINISTRATOR and EDITOR
Gregory J. Johnson
(814) 865-8207 gjj1@psu.edu

STAFF ASSISTANT
Lori Mowery
(814) 865-3264 llm1@psu.edu

WORLD WIDE WEB
www.arl.psu.edu/areas/imast/imast.html

NAVY PROGRAM MANAGER
James G. Mattern
(703) 602-9570 ext. 453
matternjg@navsea.navy.mil

©2000. The iMAST quarterly newsletter is published by the Institute for Manufacturing and Sustainment Technologies of the Applied Research Laboratory at Penn State, University Park, Pa. iMAST is a nonprofit organization sponsored by the U.S. Navy Manufacturing Technology (MANTECH) Program, Office of Naval Research, under Navy Contract N00039-97-D-0042. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the U.S. Navy. Send mail list requests or address corrections to: iMAST Administrator, ARL Penn State, P.O. Box 30, State College, PA 16804-0030 or e-mail: cvo1@psu.edu
Parcel delivery address (UPS, FedEx, USPS): N. Atherton St. Rear; Research Building West, State College, PA 16804.

Penn State is an equal opportunity/affirmative action university.
This publication can be made available in alternative media on request.
U.Ed. ARL 00-13

IN THIS QUARTERLY

DIRECTOR'S CORNER

Changing of the Guard

During the first half of year 2000, substantial changes have been made in the iMAST organization. First, the iMAST Center of Excellence organization has been

administratively moved from the Materials and Manufacturing Office. iMAST now reports directly to the Director of the Applied Research Laboratory, Dr. Raymond Hettche. This move simplifies center management procedures. Further, it enhances center visibility and accessibility within the Applied Research Laboratory. Externally, this move should emphasize the importance ARL Penn State places on the organization's role in supporting Navy and Marine Corps manufacturing technology development. As noted on the cover, Mr. Robert Cook has been selected as the new director of iMAST, effective 1 July 2000. Mr. Cook, a retired Navy Captain, brings extensive experience in undersea technology and submarine operations to the leadership of iMAST. Mr. Cook additionally brings excellent credentials, having served as a Navy acquisition professional executive. Sean Krieger, our Navy-Marine Corps RepTech program manager, will report directly to Mr. Cook within the organization structure. Mr. Cook will be working closely with Dr. Thomas Donnellan, the newly appointed head of the Materials and Manufacturing Office. This will facilitate coordination of iMAST project execution. We wish both leaders well in their new assignments. I will continue to support both organizations in the role of chief scientist.

The feature article this month describes the High Velocity Particle Consolidation (HVPC) process. This process was previously referred to as Cold Gas Dynamic Spraying (CGDS) in its application as developed under Office of Naval Research ManTech sponsorship within iMAST. Originating in Russia, this inexpensive high-rate coating technology is very versatile. It is capable of coating virtually any homogeneous substrate with some other material at relatively low temperatures. For example, we have coated copper on plastic and titanium on aluminum at temperatures below 200°C. We have achieved major successes, detailed in the article, in a variety of applications where its use has provided enhanced performance components at very low cost. It is an excellent example of our ability to develop and prototype high-payoff processes that are technically challenging and carry a risk too high for industrial adoption until feasibility has been thoroughly proven. We anticipate that our ManTech-developed HVPC facility will be used extensively by industrial partners to prototype multiple applications of this technology.

I call your attention to the efforts on-going relative to ARL's sponsorship of a laser processing applications conference in support of the Department of Defense. Our Institute Notes section has more details. This is a great opportunity for executive management to grasp future application considerations in laser processing.

Please feel free to contact any of our staff if you have any questions and/or would like to arrange a visit to see our facilities.

Paul Kurtz

PENNSTATE iMAST

MATERIALS PROCESSING TECHNOLOGIES | MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES | LASER PROCESSING TECHNOLOGIES | ADVANCED COMPOSITES MATERIALS TECHNOLOGIES | NAVY/MARINE CORPS REPAIR TECHNOLOGIES

FEATURE ARTICLE

Focus on Materials Processing Technologies

High-Velocity Particle Consolidation Technology

by Maurice F. Amateau, Ph.D. and Timothy J. Eden, Ph.D.

The Applied Research Laboratory at Penn State has established a High-Velocity Particle Consolidation (HVPC) facility to address a number of applications for the Department of Defense (DoD) and industry. HVPC is an economical and versatile technology used to apply coatings which improve the surface characteristics of materials. Coatings have been used to improve wear resistance, corrosion resistance and, in the manufacturing process, to reduce the weight of the final product.

HVPC is the process of applying coatings by exposing a metallic or ceramic substrate to a high-velocity (300–1000 m/s) gas jet, loaded with small (1–50 mm) solid particles. The supersonic gas jet accelerates the particles to velocities of 400–1000 m/s. Upon impact, the solid particles deform and bond with the substrate. Particles continue to impact and bond, with the particles already deposited, resulting in a uniform coating with very little porosity. The deposition rate for HVPC can be as much as 15 kg/min or higher. The technology was developed in the mid-1980s at the Institute of Theoretical and Applied Mechanics of the Siberian Division of the Russian Academy of Science in Novosibirsk.[1] The technology was later patented in the United States in 1994.[2] The inventors have shown that the technology can be used to apply a wide variety of pure metals, alloys, and alloy/ceramic powder mixture coatings on a number of different substrate materials.[3,4]

The basic HVPC process is shown in Figure 1. A compressed gas (typically air, nitrogen, or helium) at pressures from 1–3 MPa is expanded through a converging-diverging or

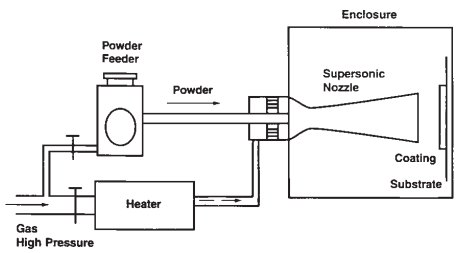


Figure 1. Schematic diagram of the High-Velocity Particle Consolidation coating equipment. The nozzle and gas heat can be mounted on a robot for coating complex surfaces.

DeLaval nozzle where it leaves the nozzle at supersonic speed (300–1200 m/s). Powder is introduced into the gas flow slightly upstream of the converging portion of the nozzle. The expanding gas rapidly accelerates the particles to very high velocities. The velocities ranges from 180–1000 m/s depending on powder size and material. A gas heater is used to increase the gas temperature prior to entering the nozzle. This results in an increase in the gas velocity and particle temperature. Heating the particle increases the ductility of the particle and both effects improve the deposition efficiency.[5] In the diverging portion of the nozzle, the gas rapidly expands causing the gas temperature to drop. As they accelerate, the particles begin to cool. But because the residence time in the nozzle is short, the temperature decrease is relatively small. The particles impact and bond to a substrate located approximately 25 mm from the exit plane of the nozzle. The distance from the nozzle can be adjusted to change the width of the coating and the sticking efficiency.

HVPC can be classified as a thermal spray technology. Conventional thermal spray processes include HVOF (high-velocity oxy-fuel), plasma, flame spray, laser cladding, electric arc, and electron beam vapor deposition. A fundamental difference between HVPC and other thermal spray technologies is that HVPC-applied particles are deposited in the solid state whereas other methods deposit particles on the substrate in a molten state. The deposition temperature and velocity of several different thermal spray methods are shown in Figure 2. These technologies have been used to apply coatings for improved wear and corrosion resistance, or provide a thermal barrier. Conventional thermal spray technologies

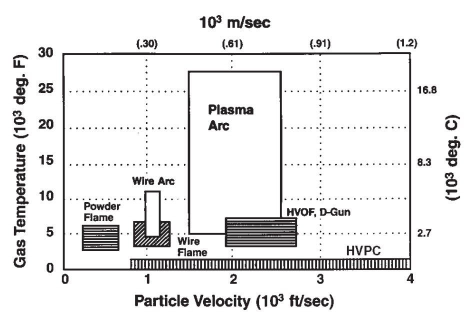


Figure 2. Comparison of conventional thermal spray technologies and HVPC technology. Note the lower temperature and high velocity of the HVPC method.

PROFILE

A highly respected metallurgical engineer within government, industry and academia, Maurice Amateau is the director of the Materials Processing Division at ARL Penn State. Dr. Amateau's research interests include the design, processing, component fabrication, and testing and analysis of metal, ceramic, and polymer composite materials.

Dr. Amateau received B.S. and M.S. degrees in metallurgical engineering from Ohio State University. He obtained his Ph.D. in Metallurgy from Case Western Reserve University. In addition to his responsibilities as director of the materials processing division at ARL, Dr. Amateau also serves as a tenured professor within the College of Engineering. Prior to coming to Penn State, he was employed with TRW, Aerospace Corporation, and International Harvester. Dr. Amateau can be reached at (814) 863-4214 or by e-mail at: <mfa1@psu.edu>.

CONTINUED FROM PAGE 3

are have certain limitations that can be addressed by HVPC. The high deposition temperature limits the substrate materials that can be coated. Coatings that experience phase transformations, excessive oxidation, evaporation, oxidation, and/or recrystallization may be difficult or impossible to apply using conventional thermal spray methods. This is particularly so for reactive materials such as titanium. Additional problems often arise from the residual stresses and deformation induced by the thermal-coefficient-of-expansion mismatch that develops as the coat and substrate cool down after deposition. Even if the coating remains bonded to the substrate, residual stresses may cause unacceptable distortions which significantly weaken the bond strength or accelerate fatigue failures. This results in reduction of the coating usefulness.

HVPC addresses many of the problems associated with conventional thermal spray techniques. The lower deposition temperatures eliminate the problems associated with recrystallization in both the coating and substrate. Oxide contamination is greatly reduced. Coatings can be applied to a wider variety of substrates and residual stresses are reduced. Precision coating of 1–2 mm can be applied with minimal masking. Thick coatings can readily be built-up making HVPC a technology for rapid prototyping. Because there are no molten materials in HVPC, the process is inherently safer than other thermal spray methods. Noise levels are lower and there are no metal fumes. The process requires less space than conventional thermal spray methods. There is little, if any, change to the powders during high-velocity particle consolidation, so the powders can be recycled to improve the economics of the process. HVPC systems are less complex and do not require a large capital investment compared to other methods.

The HVPC facility at ARL is shown in Figure 3. The nozzle (refer to Figure 1) and the gas heater are mounted on a six-axis robot. The robot is enclosed in an acoustic room that contains the

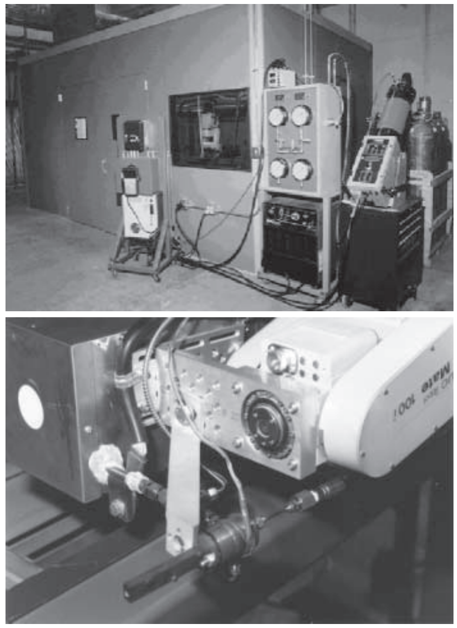


Figure 3. (Top) The HVPC facility located at the Applied Research Laboratory/Penn State. (Bottom) The nozzle and gas heater mounted on a 6-axis robot used to coat complex parts.

noise. In addition, the robot a multi-axis turntable capable of holding up to 100 kgs is available for large circular parts. The over-spray and gas that flows through the nozzle are collected inside the room and carried to a dust collector that traps all particulate down to the submicron level. A cyclone separator can be put inline to collect the powders for recycling. Nitrogen gas at pressures up to 1.6 MPa is supplied by vaporizing liquid nitrogen from a large tank. If higher pressures are required, a booster pump is available to increase the pressure up to 3.1 MPa. The system is also equipped to use bottles of high-pressure gas. This allows great flexibility in gas that is used and the parts that can be coated.

A partial list of the coatings that have been successfully applied by HVPC is shown in Table 1; other material systems are possible. Hard materials such as chromium-carbide (Cr_3C_2) can be applied if they are mixed with 25 percent binder metals. It has also been shown that aluminum and zinc can be used to coat ceramic and glass materials and form good bond strength. Work continues on developing new coatings and better methods of applying those coatings.

Table I. Coating Materials.

Powder Material	Gas	Substrate
Aluminum	N_2	Metal, Ceramic
Zinc	N_2	Metal, Ceramic
Cadmium	N_2	Metal
Tin	N_2	Metal
Silver	N_2	Metal
Copper	N_2	Metal
Nickel	N_2	Metal
Titanium	N_2	Metal
Cobalt	N_2	Metal
Iron	N_2	Metal
Niobium	N_2	Metal
Al12Si	N_2	Metal
Al6061	N_2	Metal
CCC (Al 9Ce 5Cr 2.8 Co)	N_2	Metal
Pech 1 (Al 12 Zn 3Mg 1 Cu 0.25Mn 0.2Cr 0.2Zr)	N_2	Metal
NYCZ (Al 14.5 Ni 8.2Y 2.7Co 1.9Zr)	N_2	Metal
FCW (Al 9Fe 7Ce 0.4W)	N_2	Metal
Al Bronze (Cu 10Al, Cu 9.5Al 1Fe)	N_2	Metal
Cu 36Ni 5Zn	N_2	Metal
Cu 38Ni	N_2	Metal
Nichrome (80/20)	N_2	Metal
Ni 5Al	N_2	Metal
Cr_3 C_2 –25Ni Cr	N_2	Metal
Co 29Cr 6Al 1Y (Amdry 920)	N_2	Metal
Co 32Ni 20Cr 8Al	N_2	Metal
316 St. Steel	N_2	Metal
Ancorsteel 1000	N_2	Metal
Ti 35Zr 10NI	N_2	Metal
Al Alloys + SiC (15%) (No. 12-17)	N_2	Metal
Al, Zn + 10-15% HA (HA-Hydroxyapatite)	N_2	Metal
Al + 50Cu (Mixture)	N_2	Metal
Cu + 50Ni (Mixture)	N_2	Metal
Rhenium	N_2	Metal
Molibdenium	He	Metal
Ni 23Co 20Cr 8.5Al 4Ta 0.6Y (Amdry 997)	He	Metal
Inconel 718	He	Metal
Diamalloy 1005 (Similar to Zuconel 625)	He	Metal
Ni Base Superalloy AF 115 (Ni 15Co 10.7Cr 5.9W 3.9Ti 3.8Al 2.8Mo 1.7NI 0.75H)	He	Metal
Ni 20 graphite (composite) (Amdry 954)	He	Metal
Ni 45Cr 4Ti (Ametek 55)	He	Metal
Al-Ni-Bronze	He	Metal
Hot Work Tool Steel AISI H13	He	Metal
WC-21Co	He	Metal
Co-106-1	He	Metal
Co 32Ni 21Cr 8Al 0.5Y	He	Metal

The High-Velocity Particle Consolidation process has been used to successfully apply a wide variety of coatings on a number of different substrates for several DoD and industrial applications. The project exploits the capabilities of HVPC and details will be given for each project.

Advanced Amphibious Assault Vehicle (AAAV) Road Wheel

The road wheel on the track system for the AAAV is made of aluminum with a steel wear ring riveted to the side as a wear surface (Figure 4). The total weight of the wheel is approximately 28.5 kgs (62.75 lbs) with the steel ring weighing just over 9 kgs (20 lbs). The steel wear

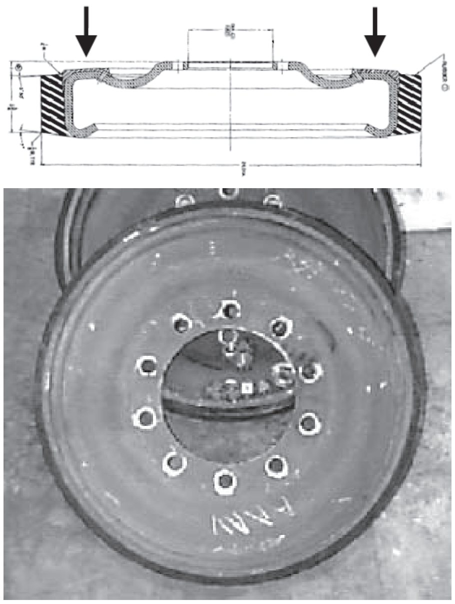


Figure 4. (Top) Schematic of the AAAV road wheel showing the steel wear ring. (Bottom) Road wheels prior to coating.

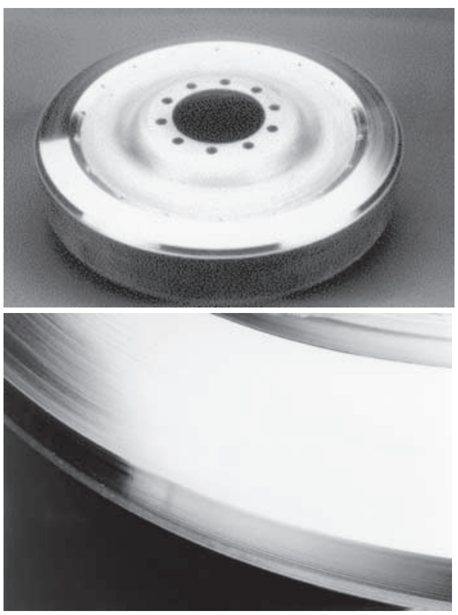


Figure 5. (Top) AAAV road wheel coated with Al-9Ce-5Cr-2.8Co+15%SiCp. (Bottom) Wheel after machining.

ring was replaced with a lightweight wear resistant coating applied by HVPC (Figure 5). A coating was selected that had similar wear properties to steel. The coating was Al-9Ce-5Cr-2.8Co+15 volume percent SiC. Helium was used as the carrier gas. The use of HVPC to apply the lightweight coating reduced the weight of the road wheel by 6.8 kgs (15 lbs). There are 28 wheels on one vehicle resulting in a total weight savings of 191 kgs (420 lbs). The wheels are currently being road tested on a vehicle. The vehicle has been driven over 1610 miles with the new road wheels installed in the track system. The wear performance has met expectations.

Aircraft Catapult Piston

The aircraft catapult piston, shown in Figure 6, is used to launch aircraft from the flight decks of aircraft carriers. The piston is made of Al 2618-T6 with a manganese bronze piston guide. The piston is driven by high-pressure steam through a cylindrical (ASTM 387, Grade 2, Class 1) tube. The increasing weight of the aircraft has increased the wear on the guide. An economical solution was needed to improve the wear resistance, maintain the reliability, and extend the life of the pistons. HVPC was used to apply a coating of Nickel-Aluminum-Bronze (NAB) to the wear panels. The coated panels had good wear resistance and very good bond strength between the coating and the substrate. The next effort, currently underway, is to use NAB applied by HVPC to replace the guide on a full-scale piston.

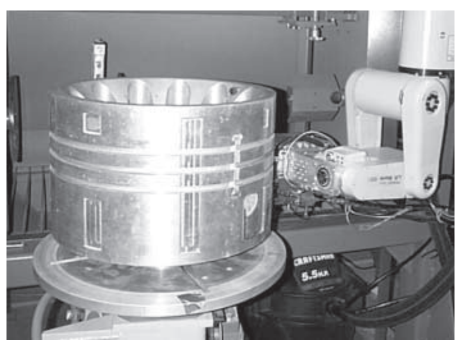


Figure 6. Aircraft catapult piston in the HVPC facility prior to applying the nickel-aluminum bronze coating.

AAV Armor

The AAV appliqué armor is made of a steel rubber laminate. The steel is coated with an epoxy paint system that protected the steel from corrosion. Once the CARC coating was damaged, the steel panels quickly began to corrode (Figure 7). The corrosion spreads from the damage site, reducing the effectiveness of the armor. A program was developed to prolong the life of the armor. Part of the

Figure 7. A corroded AAV appliqué armor panel that has been exposed to service conditions.

program investigated the use of a corrosion resistant coating applied to the steel before it was painted. This coating would provide protection after the CARC sustained damage. Sections of the steel armor were coated with aluminum, zinc, and a mixture of 85 percent zinc and 15 percent aluminum by weight using HVPC and also thermal spray. Sections of the panel were tested in two alternate immersion test matrices. One of the tests was conducted at the La Que Center for Corrosion Technology in Wrightsville Beach, North Carolina. In this test the panels were immersed in filtered seawater for 1 hour and then allowed to dry in air for 23 hours. This test lasted six months and represented an accelerated corrosion test. A panel coated with aluminum powder at the start of the test is shown in Figure 8. The same panel is shown in Figure 9 after six months. There was little evidence of corrosion on any of the coated panels. A similar test was conducted at ARL where the immersion cycle was 10 minutes in artificial seawater and 50 minutes in air. To compare the effectiveness of the coatings, polarization measurements were taken. Data from these tests were used to determine a corrosion rate. This corrosion rate, shown in Figure 10, was used to evaluate the coatings. Initial results show that the panel coated with aluminum by HVPC has the lowest corrosion rate of the panels tested. Additional coated panels are currently being evaluated.

Titanium Coatings

One of the most promising areas for HVPC is in the application of titanium

CONTINUED FROM PAGE 5

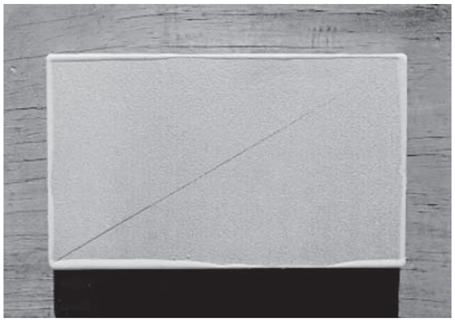


Figure 8. A section of AAV appliqué armor that was coated with aluminum powder prior to alternate immersion testing. The panel has been scored to evaluate corrosion damage protection.

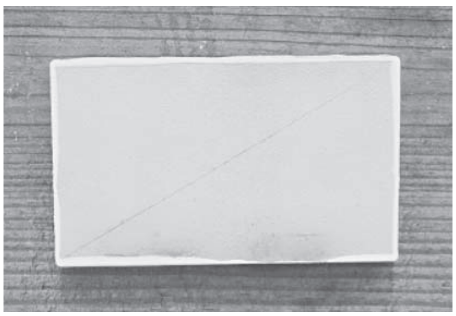


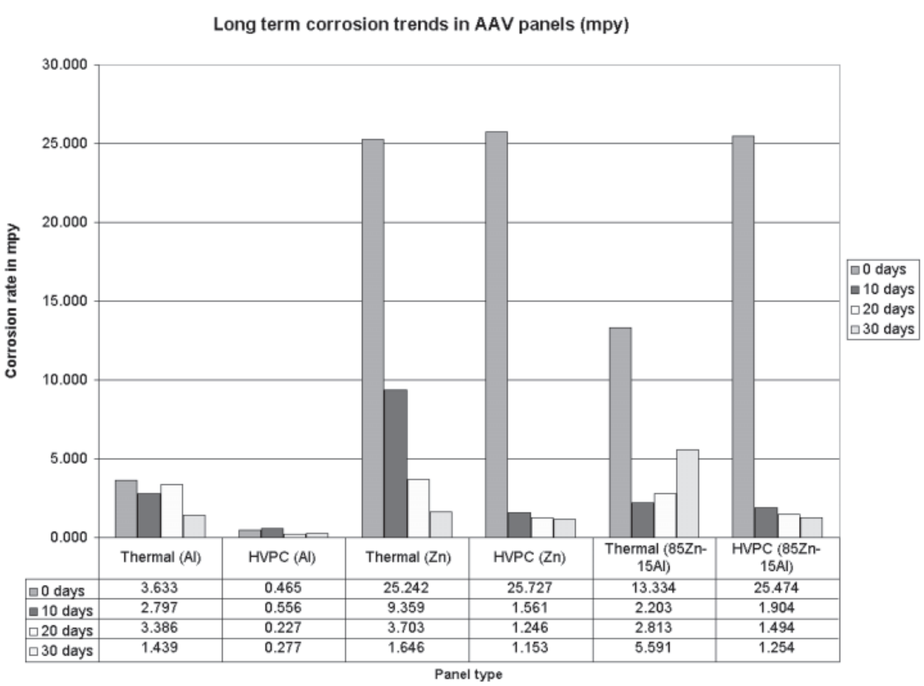
Figure 9. A section of coated armor after six months of alternate immersion testing in sea water. The discoloration at the bottom was caused by a stain from the specimen rack.

powder. Some of the problems associated with coating materials with titanium include bond strength, ability of titanium to bond to other materials, oxidization, and wear resistance. HVPC has shown excellent potential for applying titanium coatings up to several millimeters thick on several materials (Figure 11). There are several potential applications for this technology. One is build-up worn areas on titanium parts such as drive shafts and pistons. Another advantage is to apply wear resistant coatings on titanium. For example, a long lasting fretting resistant coating could be used to coat the dovetails on rotating titanium parts in jet engines.

Current ARL Developments

Researchers at ARL are working to improve the economics of HVPC by improving the efficiency of the process and developing methods for recycling the powder. We are also developing a design methodology that will be used to configure a complete HVPC system for coating complex parts. Part of the design methodology is to develop a multiphase computational fluid dynamic (CFD) code that can be used as a design and analysis tool. This will allow a system to be optimized for specific applications. The design process includes configuration of entire turnkey systems. This includes all the related hardware, quality assurance, powder handling, and data recording systems.

Figure 11. Parts that have been coated with titanium powder using HVPC can be machined to meet final dimensional requirements.



	Thermal (Al)	HVPC (Al)	Thermal (Zn)	HVPC (Zn)	Thermal (85Zn-15Al)	HVPC (85Zn-15Al)
0 days	3.633	0.465	25.242	25.727	13.334	25.474
10 days	2.797	0.556	9.359	1.561	2.203	1.904
20 days	3.386	0.227	3.703	1.246	2.813	1.494
30 days	1.439	0.277	1.646	1.153	5.591	1.254

Figure 10. Corrosion rate for AAV appliqué armor panels coated with Al, Zn, and 85Zn-15Al. The panels were coated using thermal spray and HVPC methods.

Conclusion

HVPC is a proven coating technology that has shown great flexibility in coating a wide variety of substrates. ARL has established a unique HVPC facility that includes a multi-axis robot capable of coating complex parts. HVPC has successfully been used in the areas of corrosion protection and wear resistance.

References

1. A.P. Alknimov, V.F. Kosarev, and A.N. Apayrin. "A Method of Cold Gas Dynamic Deposition", *Dokl Acad. Nauk SSSR, 318*, pp. 1062-1065, 1990.
2. A.P. Alknimov, V.F. Kosarev, and A.N. Apayrin. "Cold Gas Dynamic Spray Method for Applying a Coating", U.S. Patent 5,302,414, April 12 1994.
3. A.E. Segall, et. al., "A Cold-Gas Spray Coating Process for Enhancing Titanium," *Journal of Metals*, September, 1998, pp 52–54
4. R.C. Dykhuizen and M.F. Smith, "Gas Dynamic Principles of Cold Spray," *Journal of Thermal Spray*, June 1998, Vol. 7 pp 205–212
5. A.P. Alkhimov, et. al., "Gas-Dynamic Spraying. A Study of a PLane Supersonic Two-Phase Jet," *Journal of Applied Mechanics and Technical Physics*, Vol. 38, No. 2 pp 324–330, 1997.

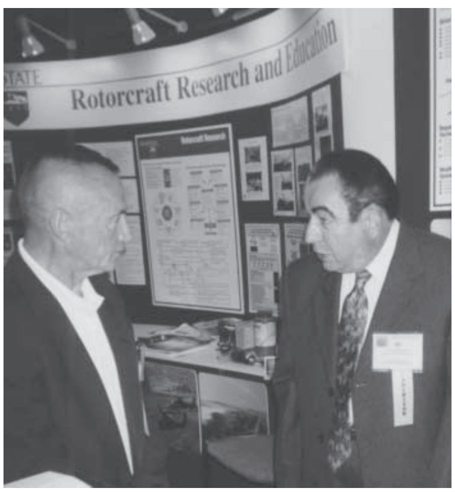
Dr. Tim Eden (far right), a research associate with ARL's Materials Processing Division, explains operation of ARL's High-Velocity Particle Consolidation system to Paul Connelly (far left) and Mike Canaday (second from left), NSWC Dahlgren mechanical engineers. Dr. Maurice Amateau (second from right), director of the Materials Processing Division, looks on.

NSWC Dahlgren Visits iMAST

Members of the Light Weapons Branch of the Naval Surface Warfare Center at Dahlgren, Virginia recently paid a visit to ARL Penn State to review materials-related program capabilities and to familiarize themselves with available ARL facilities. The Light Weapons Branch (G31) performs program research in naval gun weapons systems, Marine Corps weapons, and deck-launched ordnance. This effort includes system design and development, technical management, and system acquisition.

Laser Applications in DoD Manufacturing and Repair Conference Set

ARL's Laser Processing Department will host a conference designed for government acquisition professionals, repair and sustainment executives, depot and shipyard managers, research and development personnel, and OEM executives. The conference will provide an opportunity to assess current uses and new applications of this important manufacturing technology for reducing costs and improving performance of land, sea, and air military systems platforms. The four day conference will be held at The Penn Stater Conference Center from 24–27 September 2000. For more information, contact Ms. Cindy Hull at (814) 863-8865 or by e-mail at <ckh4@psu.edu>. You may also check the following web site: <http://www.arl.psu.edu/dodconference.html>.



Dr. William Scheuren, program manager, tactical technology, DARPA, discusses propulsion technology with ARL engineer, Al Lemanski.

iMAST Participates at AHS

The 56th annual American Helicopter Society Forum was recently held in Virginia Beach, Virginia. iMAST and the Penn State Rotorcraft Technology Center of Excellence participated together in grand force. This year's theme, "Expanding VSTOL Roles and Missions" drew large industry participation and guest speakers from throughout the United States. The forum provided an opportunity to communicate recent developments in the advancement and application of vertical flight technology. AHS Forum 57 will be held in Washington, D.C. in May 2001. For more information about AHS, call (703) 684-6777 or write Mr. Rhett Flater, Executive Director AHS, 217 N. Washington Street, Alexandria, VA 22314 or e-mail: <ahs703@aol.com>.

iMAST administrator, Greg Johnson (left), joins Colonel Fraser (center) and Captain Cosgrove at their Change of Command ceremony at NAS Patuxent River.

Change of Command

Colonel Eugene Fraser, USMC recently assumed command of the Naval Test Wing Atlantic at NAS Patuxent River, MD. He succeeds Captain Mike Cosgrove, USN who will be retiring. The Naval Test Wing Atlantic is the Navy's principal Atlantic flight and ground support activity for all naval aviation systems, TEAM-controlled aircraft, aircraft functions engaged in research and development, as well as test and evaluation of aircraft and aircraft systems. Colonel Fraser, a chemical engineer, will assume Captain Cosgrove's position on ARL Penn State's Materials and Manufacturing Advisory Board. Prior to assuming his current command, Colonel Fraser, a naval aviator, served as director of systems engineering in the Joint Strike Fighter (JSF) Program.

CALENDAR OF EVENTS

1 Aug	NAWC-AD Smart Squadron Industry Day ★★★★★ visit the iMAST booth	Patuxent River, MD
9–11 Aug	ONR Naval-Industry R&D Conference ★★★★★ visit the ARL booth	Washington, D.C.
14–18 Aug	Penn State Rotary Wing Technology Short Course	State College, PA
22–25 Aug	2000 Ship Production Symposium ★★★★★ visit the ARL booth	Williamsburg, VA
19–21 Sep	Modern Day Marine Expo ★★★★★ visit the iMAST booth	Quantico, VA
24–27 Sep	ARL Laser Applications in DoD Conference	State College, PA
10–11 Oct	Materials and Manufacturing Advisory Board Meeting	State College, PA
16–18 Oct	AUSA Expo	Washington, D.C.
19–20 Oct	Vice Chief of Naval Research Visit	State College, PA
29 Oct–1 Nov	AHS Powered Lift Conference	Arlington, VA
30 Oct–2 Nov	4th Annual NDIA DoD Maintenance Conference	Columbia, SC
26–30 Nov	Defense Manufacturing Conference 2000 ★★★★★ visit the iMAST booth	Tampa, FL
28–30 Jan 2001	NDIA Tactical Wheeled Vehicle Conference	Monterey, CA
3–5 Apr	AW&ST Maintenance, Overhaul and Repair Conference	Dallas, TX
10–12 Apr	Navy League Sea-Air-Space Expo 2001	Washington, D.C.

Quotable

"We have a smaller force and more missions. We are wearing out systems and wearing out people."

—William Cohen, Secretary of Defense

PENNSTATE

1855

Applied Research Laboratory
P.O. Box 30
State College, PA 16804–0030

Nonprofit Org.
U.S. Postage
PAID
University Park, PA
Permit No. 1

ADDRESS CORRECTION REQUESTED